Towards the future of “Making”: Convergence

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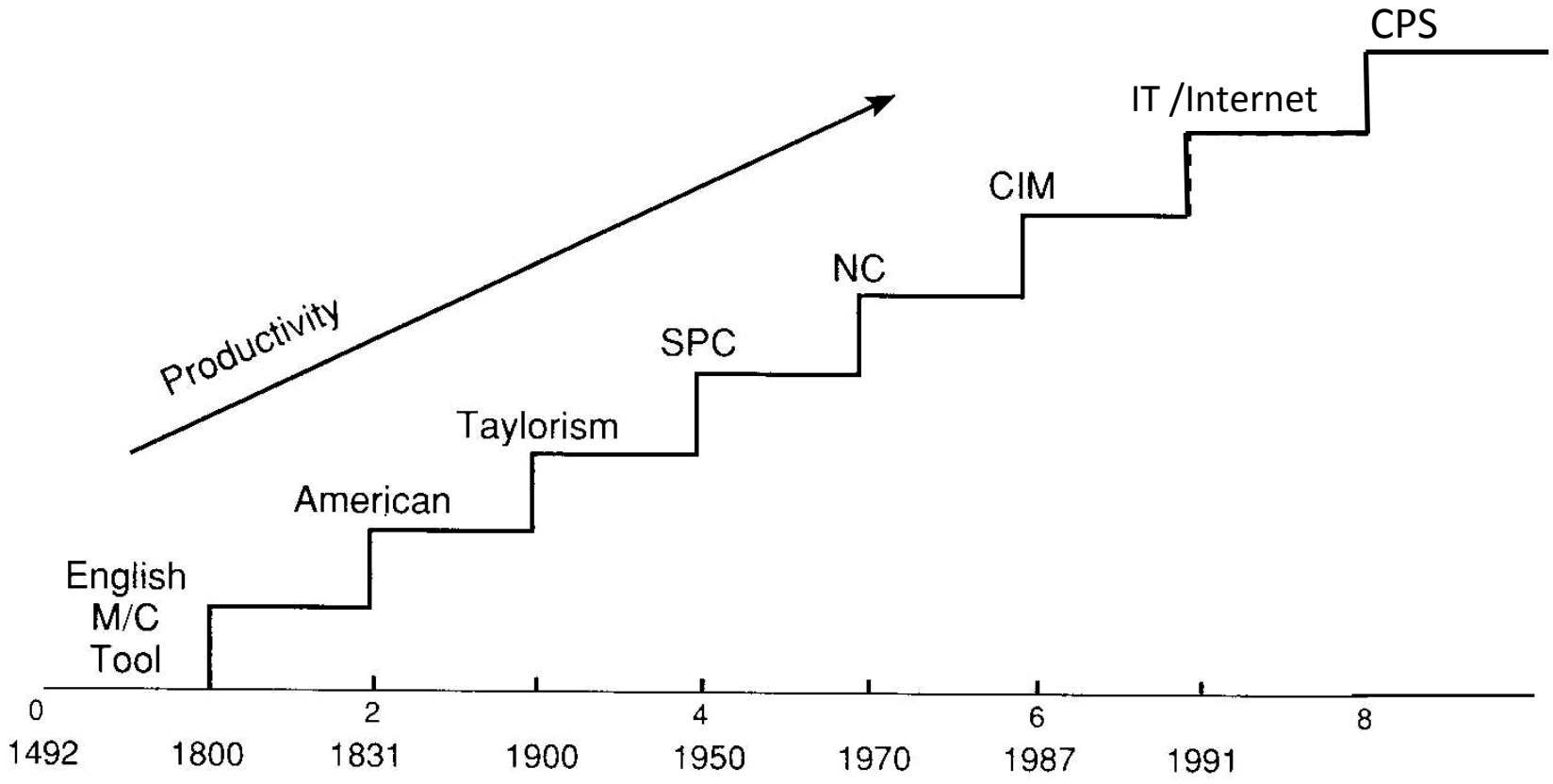
What is common among all current CPS contexts? What changes with D&M?

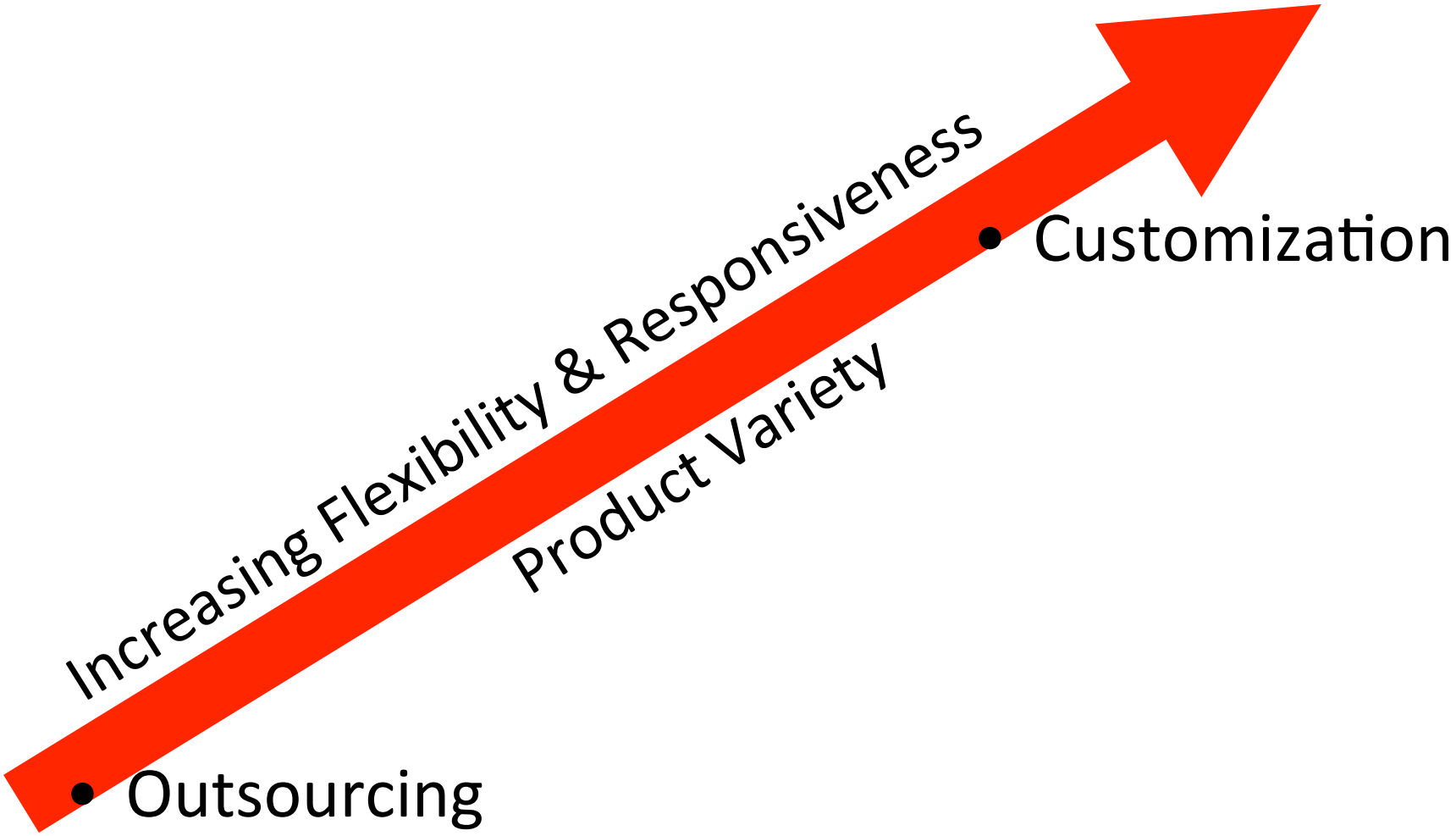
- Cyber-Physical Systems (CPS): *Orchestrating networked computational resources with physical systems [Edward A. Lee, Sanjit A. Seshia]*
- Contexts: *Already existing things/systems that are made to be improved or optimized (knowledge not new)*
- CPS in D&M*: Orchestrating the creation of products with networked computational resources with physical systems and humans in the loop*
- Contexts: *The creation and making of things with embedded software and electronics in a more open way*

Changing the context: Innovation and Productivity Follows Paradigm Shifts

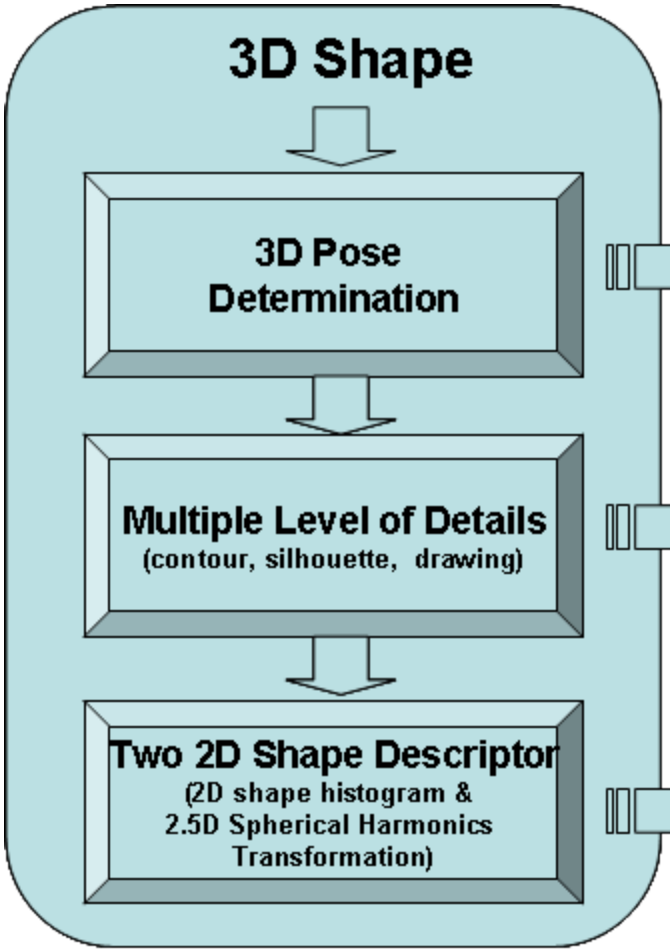


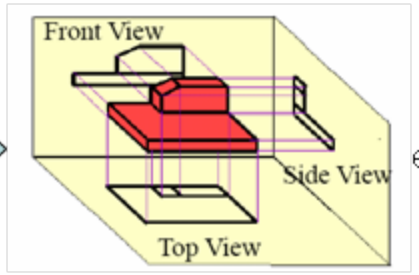
Adapted and modified from Professor Jayakumar, Harvard Business School

Competing: Time & Responsiveness



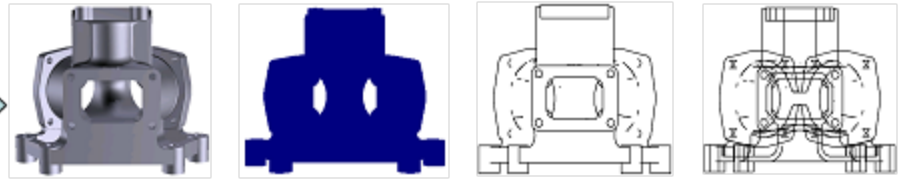
One of our proposed methods (a decade ago)



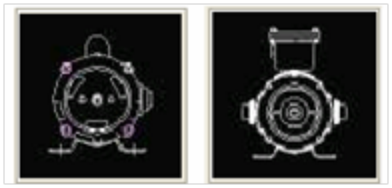


"Find a bounding box"

Simulate the process that an engineer expresses his shape idea using three views.



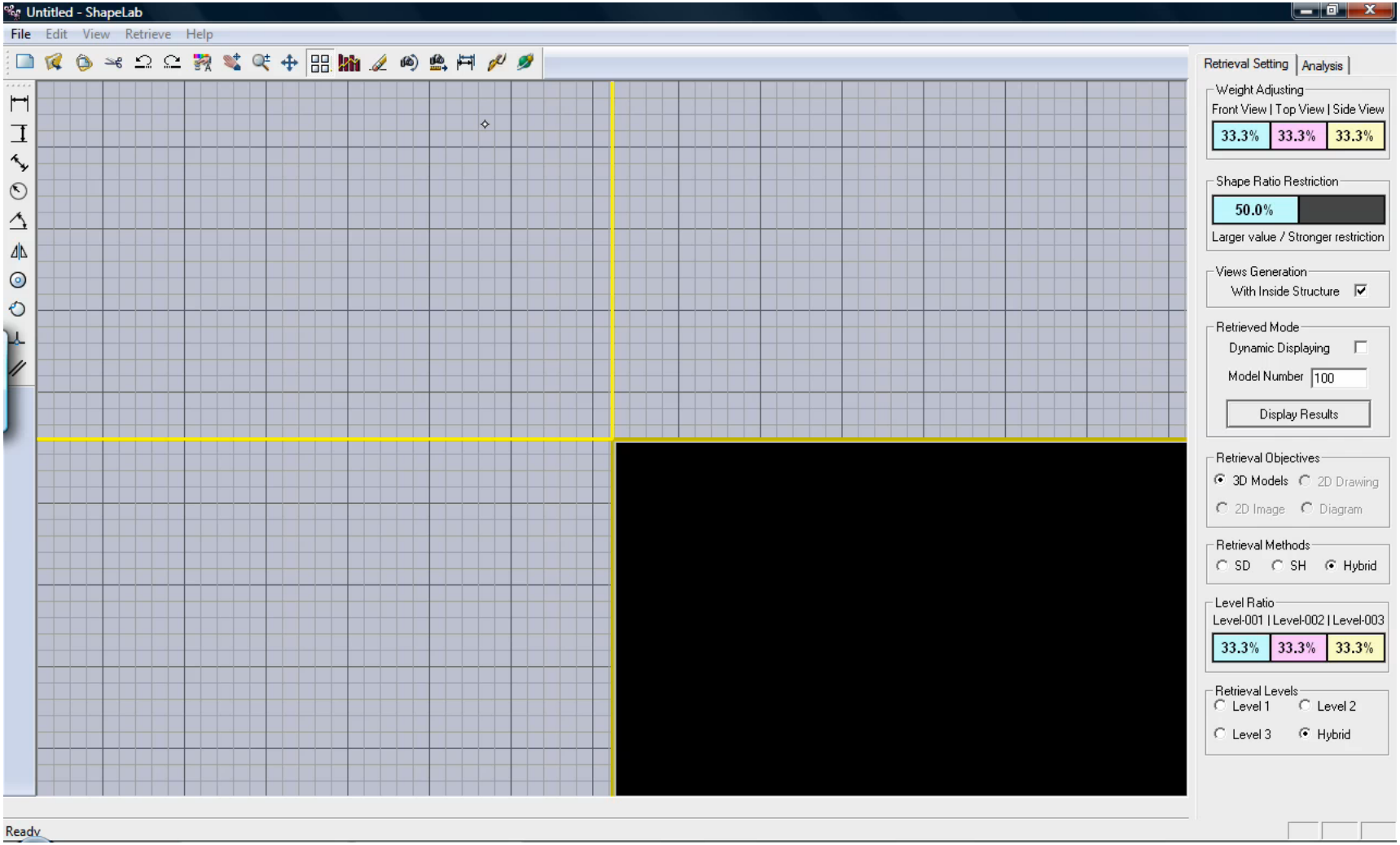
(a) a 3D model; (b) contour level; (c) silhouette level; and (d) drawing level.



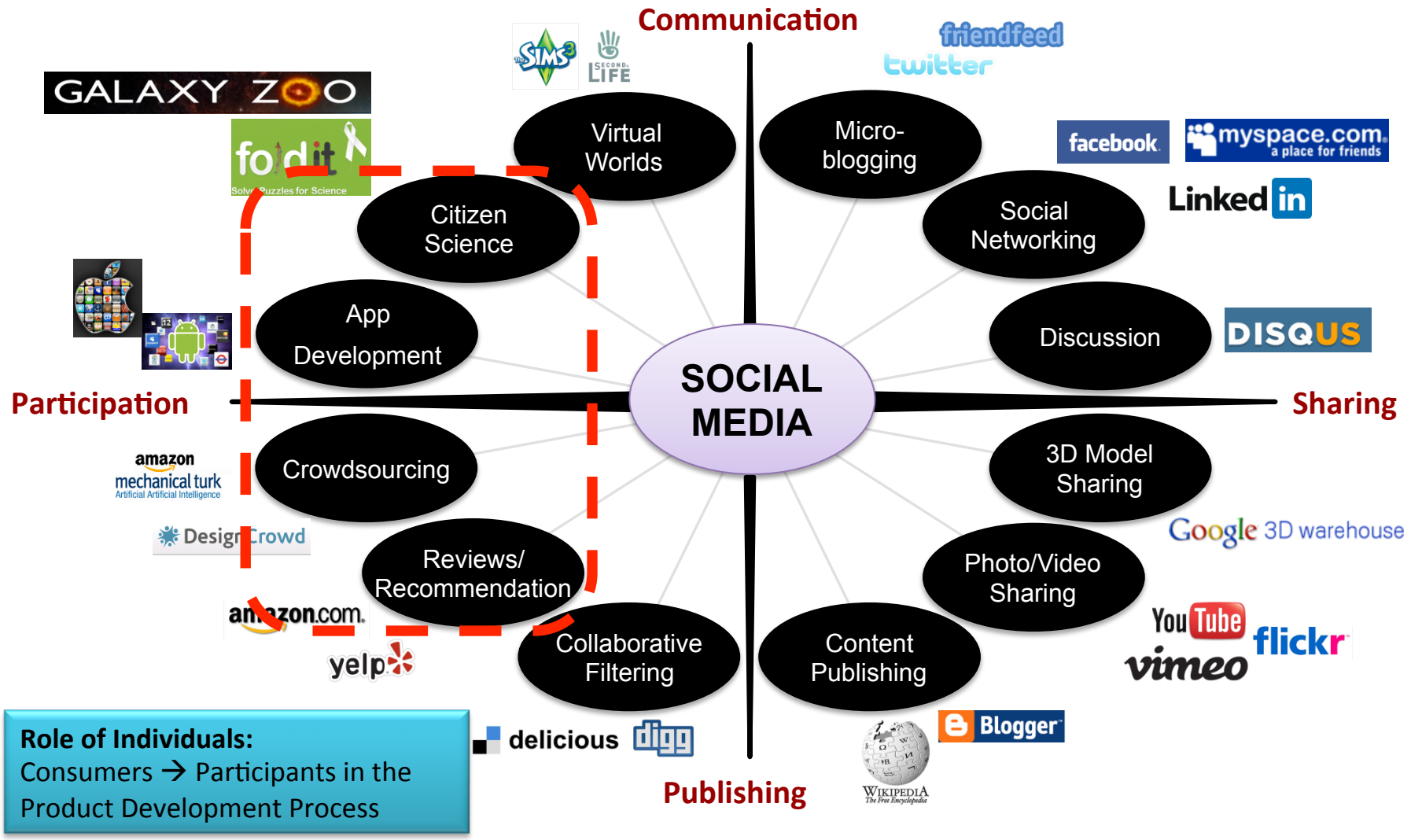
Output the similarity

Most Highly Cited Paper Awards Computer Aided Design [Elsevier, #13 ranked of over 200 CS Journal, The Times Higher Education]

Early prototype of VizSeek



Information Technology Paradigms



Role of Individuals:
Consumers → Participants in the Product Development Process

Ref: "Complex Systems Engineering by Self-Organized Virtual Communities". Jitesh Panchal [Adapted from Don Crowther]

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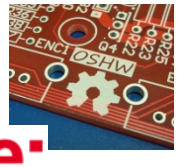
Design & Manufacturing Paradigms



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Make: technology on your time

LOCAL MOTORS

quirky

INNOCENTIVE

imaginestics

Alibaba.com

GRABCAD

Trimble. SketchUp.

RepRap

ARDUINO

Vendor-Enterprise-Consumer Communication

Vendor+Consumer Participation

Open Platforms

Prototyping

?

?

?

- Open funding networks
- Testimonials
- Makers movement
- Business Networking
- Micro-manufacturing
- Forums
- Crowdsourcing
- 3D Model Sharing
- Reviews/ Recommendation
- Specifications Sharing
- Collaborative Filtering
- Content Publishing

BUSINESS ENTERPRISE

Role of Individuals:
Consumers → Participants in the Product Development Process

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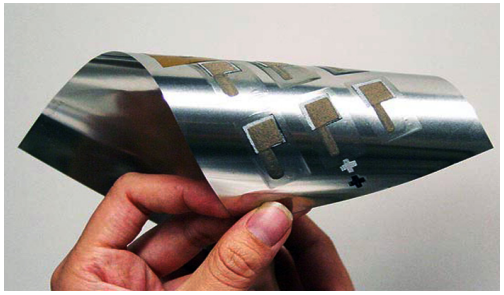
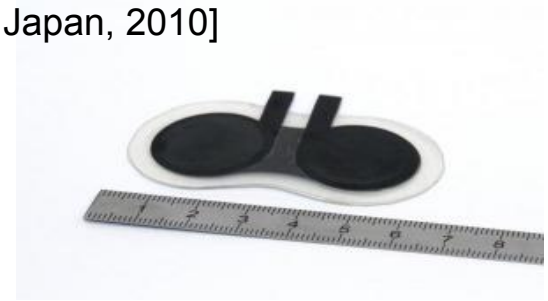
Manufacturing In 2D-3D : Current and Future Trends

Printable batteries



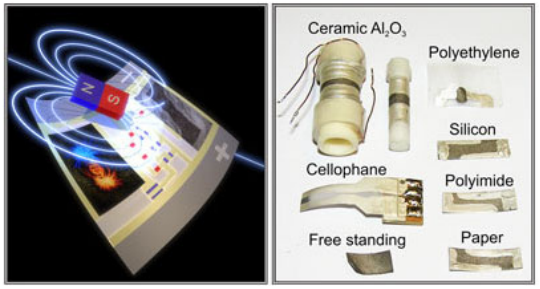
Rechargeable battery with zinc electrode [UC

Lithium-polymer battery for flexible displays [AMIC, Japan, 2010]

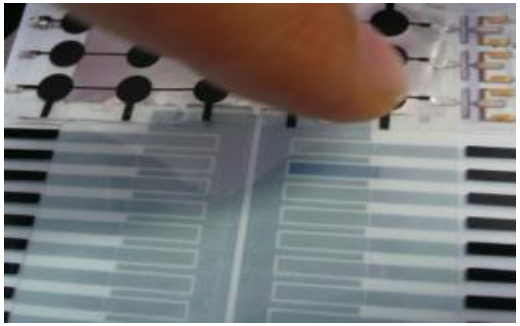


Multilayer battery by silk-screen printing [ENAS, Germany, 2009]

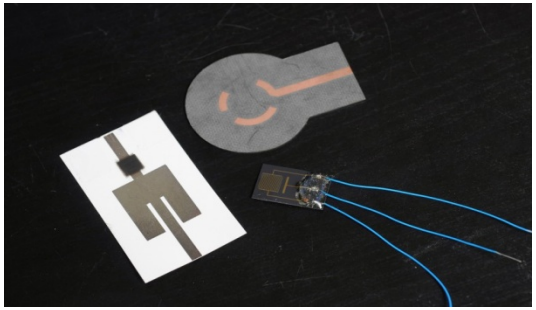
Printable Sensors



The First printable magnetic sensor [IFW-Dresden, Germany, 2012]

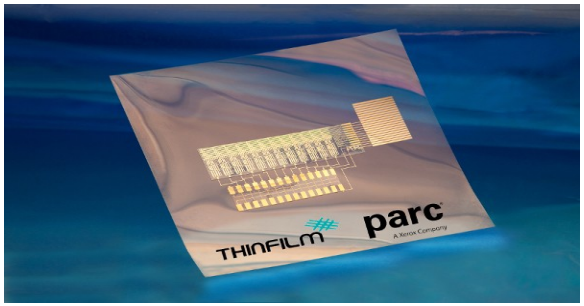


Pyroelectrical and piezoelectrical sensor by screen printing [ISC, Germany, 2011]

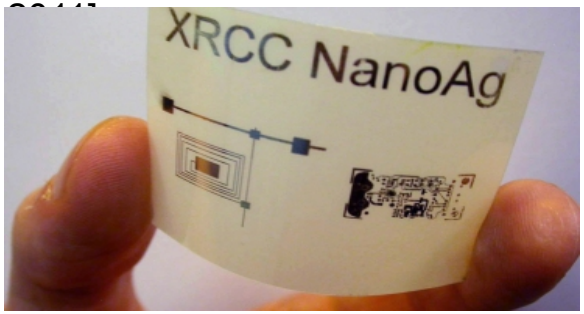


Ink-jet printable ammonia sensor for communication device [GTRI, US, 2011]

Printable Circuits



Printable circuit incorporating organic, rewritable memory & transistor [ThinFilm



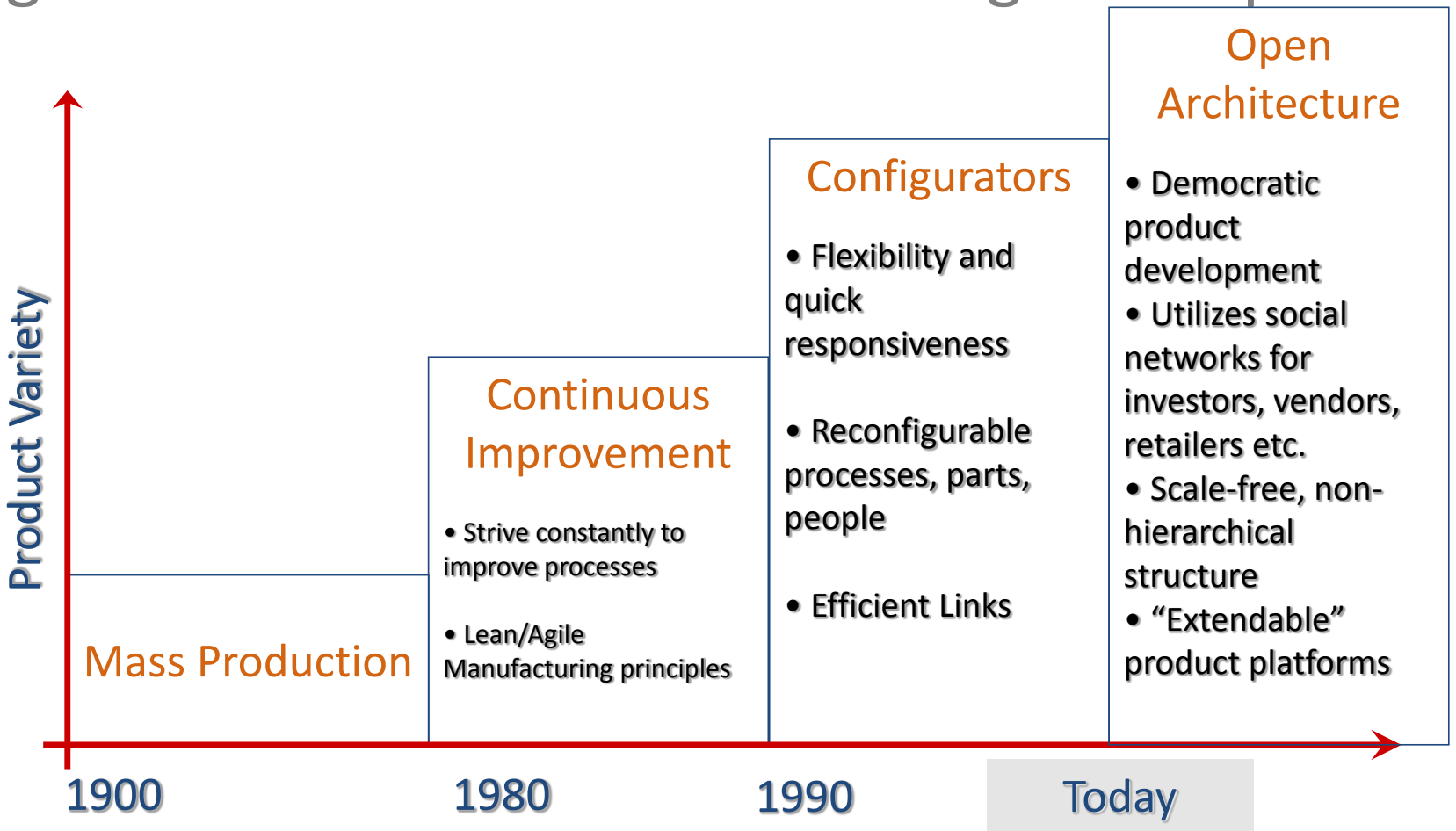
Conductive ink for printing circuits [Xerox, 2009]

Images from:

http://www.engadget.com/tag/printable+circuits/

http://www.dailycal.org http://phys.org
ww.gizmag.com http://www.sciencedaily.com
http://www.nanowerk.com/spotlight/spotid=26011.php
http://news.xerox.com/pr/xerox/NR_2009Oct27_
Xerox_Scientists_Develop_Silver_Ink.aspx

Tying Information and Manufacturing: some parallels



one → one
Enterprise to consumer

one → many
Enterprise to consumers

many → one → many
Vendors to enterprise to consumers

many → one → one
Vendors to enterprise to consumer

many → many → one
Vendors to enterprises to consumer

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Innovation by Self-organized Virtual Communities

Information-based products

Open Source Software

Linux

SourceForge has 2 million registered users and 300,000+ registered projects – July 2011

Virtual Design-Manufacturing Ecosystems

100kGarages.com

Ponoko

THINGIVERSE

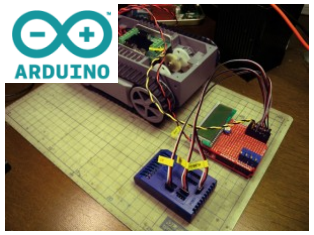
shapeways

Innovation by Self-organized Communities

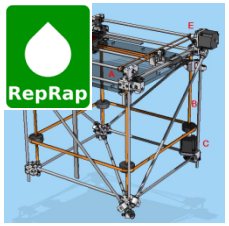
Open Source Hardware/Physical Products

bug labs

ARDUINO



RepRap



Open Source Car

"… physical products are information products during the design stage…" [von Hippel, 2005]

Ref: "Complex Systems Engineering by Self-Organized Virtual Communities". Jitesh Panchal

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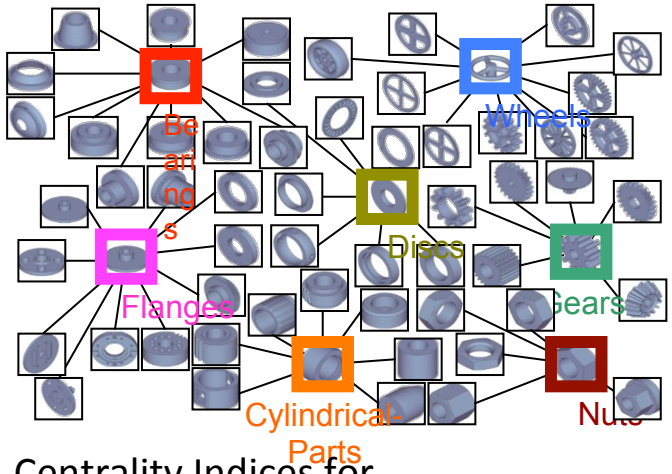
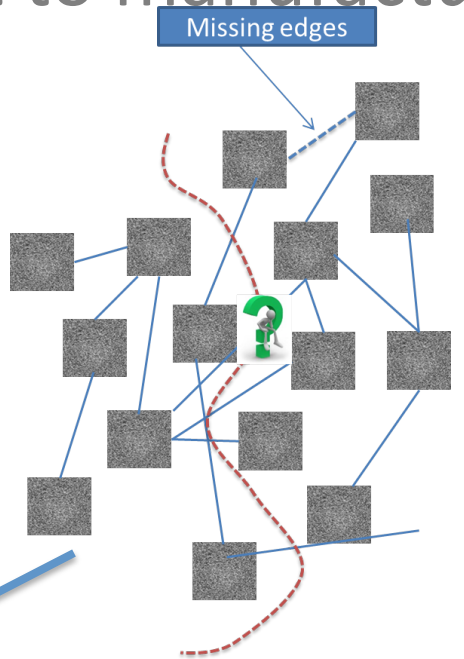
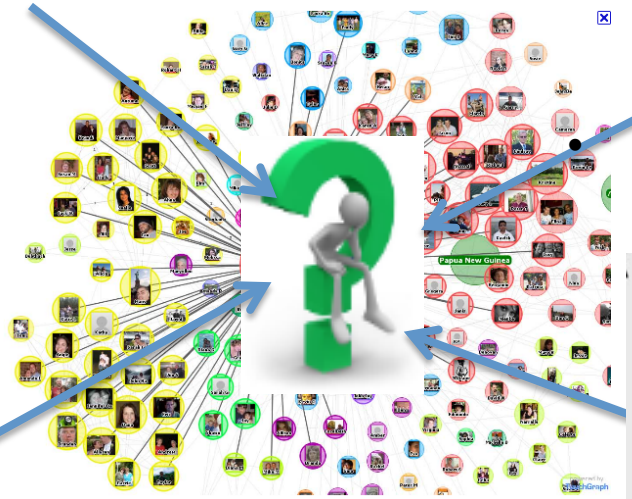
Properties of social networks relevant to manufacturing



Recommender systems for linking vendors and manufacturers

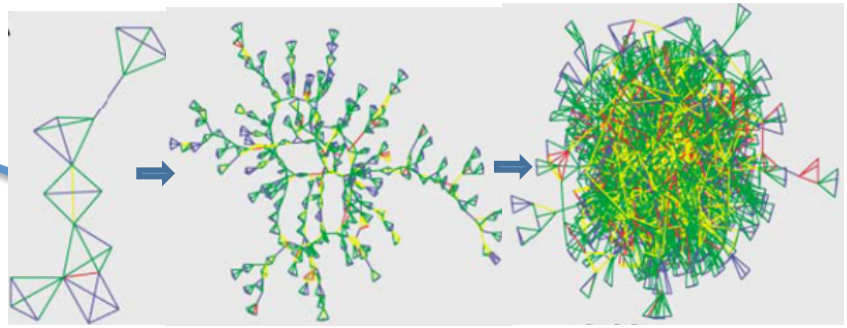


Centrality Indices for identifying key vendors



Leveraging diffusion distances used in geometry for robust product planning

Network evolution models for predicting the scope of open-architecture



Barabasi and Albert. Science (1999) **286** 509-512

Yi Fang, Mengtian Sun, Minhyong Kim, Wen Jiang and Karthik Ramani, *Heat-passing framework for assumption-free interpretation of data in networks*, submitted to PAMI, 2011

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Challenges to open-source collaboration environments

- Business models
- Psychological (Incentives)
- Legal
- Sociological (Trust)
- Product Development Process
- Supporting Platforms
- Education/ Training

Reproduced with permission from Dr.Jitesh Panchal, Purdue University

Challenges specific to 'tangible' products:

- Compatibility: standardization of dimensions, component interfaces, materials etc.
- Overhead: Higher investment in manufacturing and supply chain
- Perceived risk

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First steps: Open-source hardware

Most projects use existing Free and Open Source Software (FOSS) licenses

TAPR Open Hardware License used to address creation of tangible things:
" …it forbids anyone who receives rights under the OHL to deny any other licensee those same rights to copy, modify, and distribute documentation, and to make, use and distribute products based on that documentation."
(from www.tapr.org)

Suggested business models:

- Focus on hardware, allow individuals to build designs around it
- Create a design community around their hardware
- Focus also on services like design consulting

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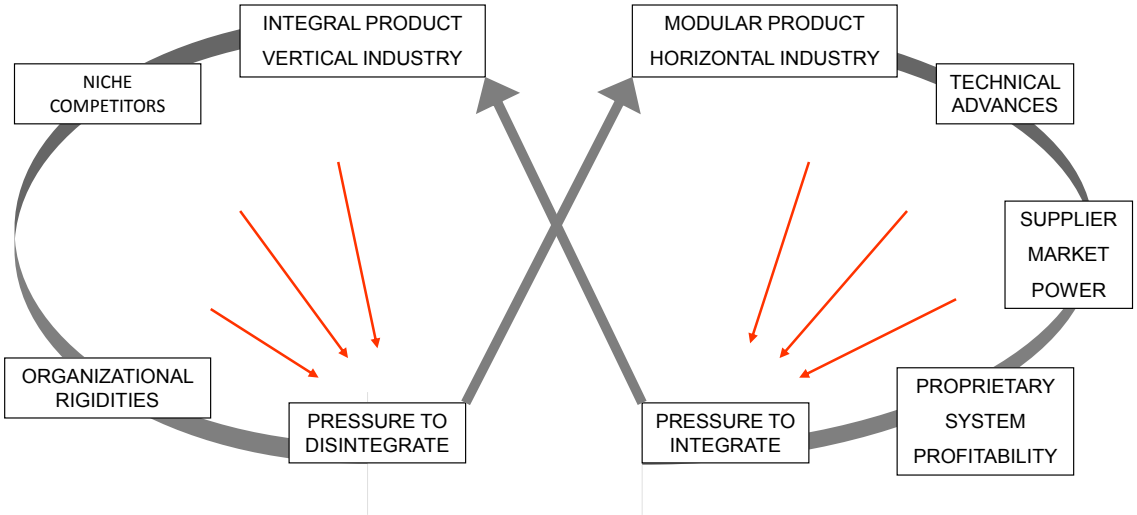
Clockspeed: the crowdsourcing version



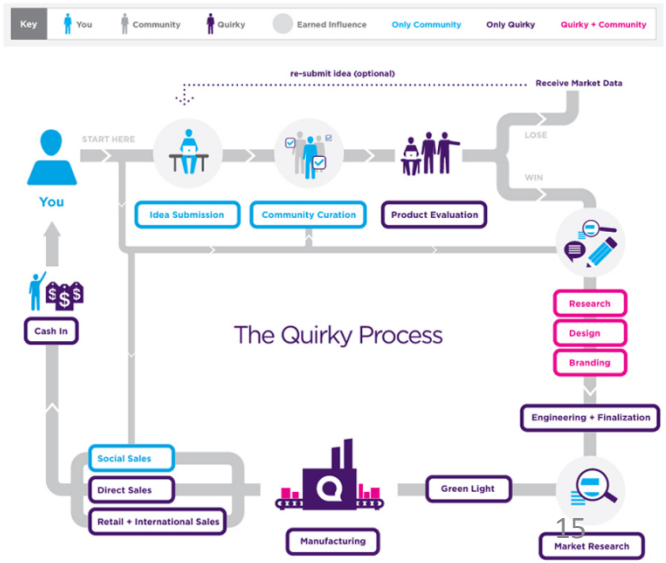
Fine and Whitney, "Is the make/buy decision a core competence?"

Local Motors company:

Combination of:
Crowdsourcing (shape and style) +
professional engineering (performance and safety) +
micro-manufacturing

Quirky:

Combination of:
Crowdsourcing (design ideas + curating, sales) +
In-house (evaluation, engineering, manufacturing, sales)



Ref: http://www.wired.com/magazine/2010/01/ff_newrevolution/; http://www.quirky.com/learn
Image source: http://en.wikipedia.org/wiki/Local_Motors

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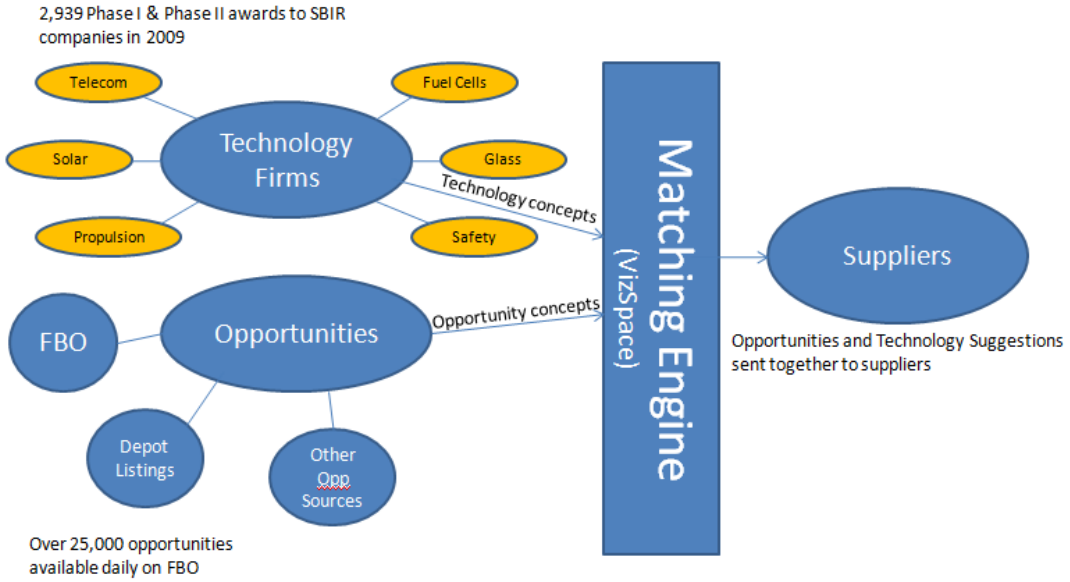
Social networking in the supply chain

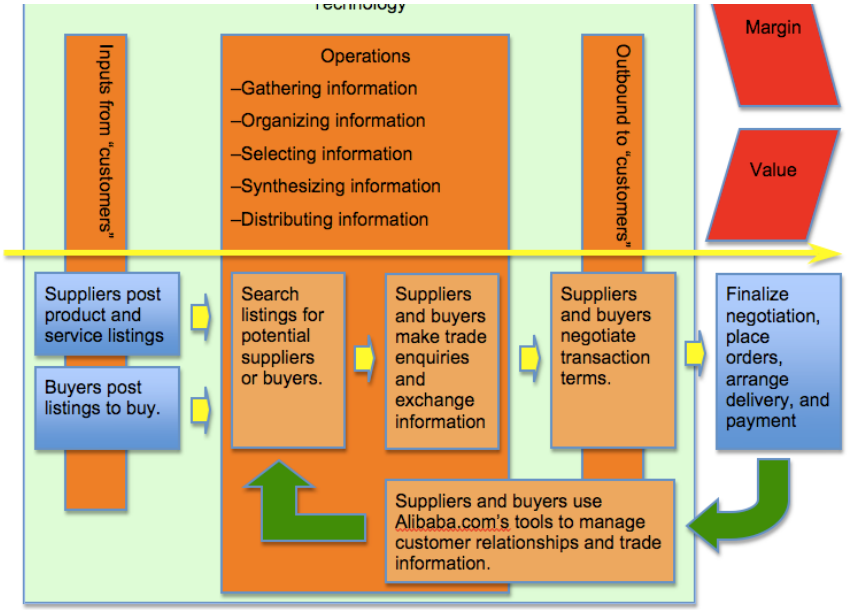
imaginestics

Using ontology for concept matching and social networking for suggesting technology to suppliers



Alibaba.com

Network of suppliers and buyers with listings, matches, and information exchange enabled through the company software



Ref: http://www.imaginestics.com/Images/Small%20Business%20Technology%20Transition%20White%20Paper%20-%20Imaginestics.pdf, Li Z, Raskin V, Ramani K. Developing engineering ontology for information retrieval. Journal of Computing and Information Science in Engineering 2008;8(1), Alibaba.com Case Write: A Consideration of a the Virtual Service Value Chain. John Haase, 2009)

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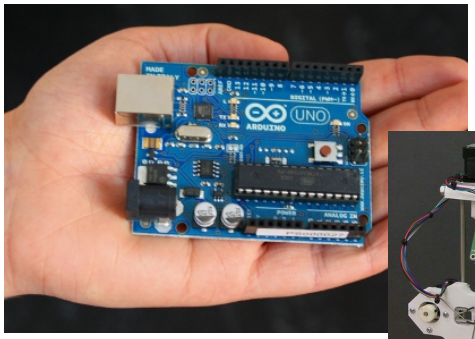
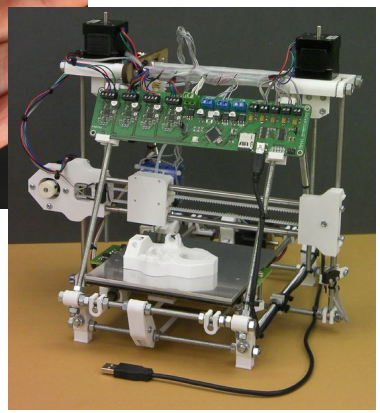
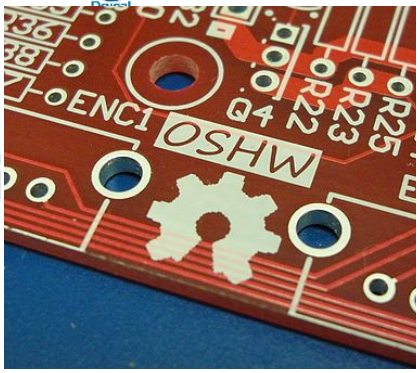
Enabling the “Do-it-Yourself” prototyping paradigm

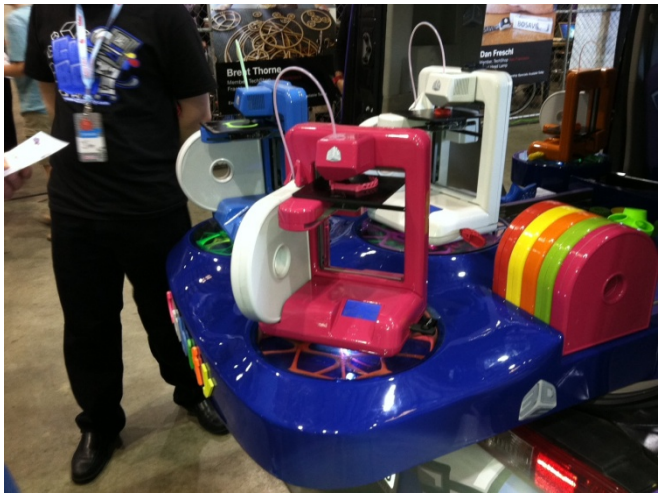




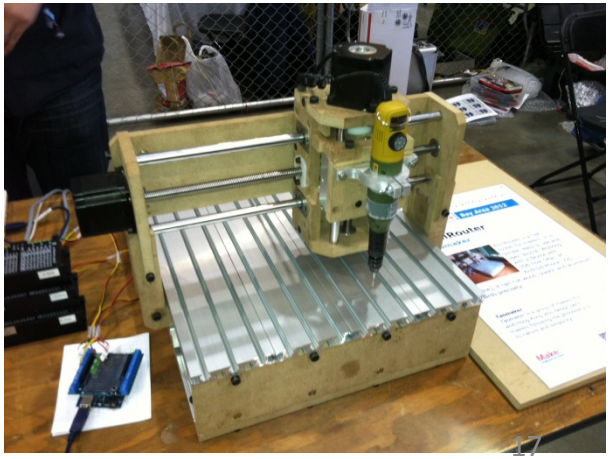
Platforms

Communities





Maker Faire®



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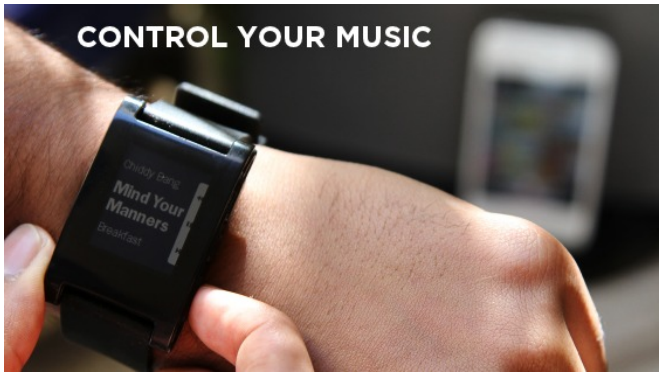
Open platform for funding innovation

KICKSTARTER

Democratizing innovation
Infrastructure for realizing ideas
Quick and Widespread dissemination of ideas



e.g. Pebble: E-Paper Watch for iPhone and Android
Raised over $3 Million in Four Days
Over $10 million to date

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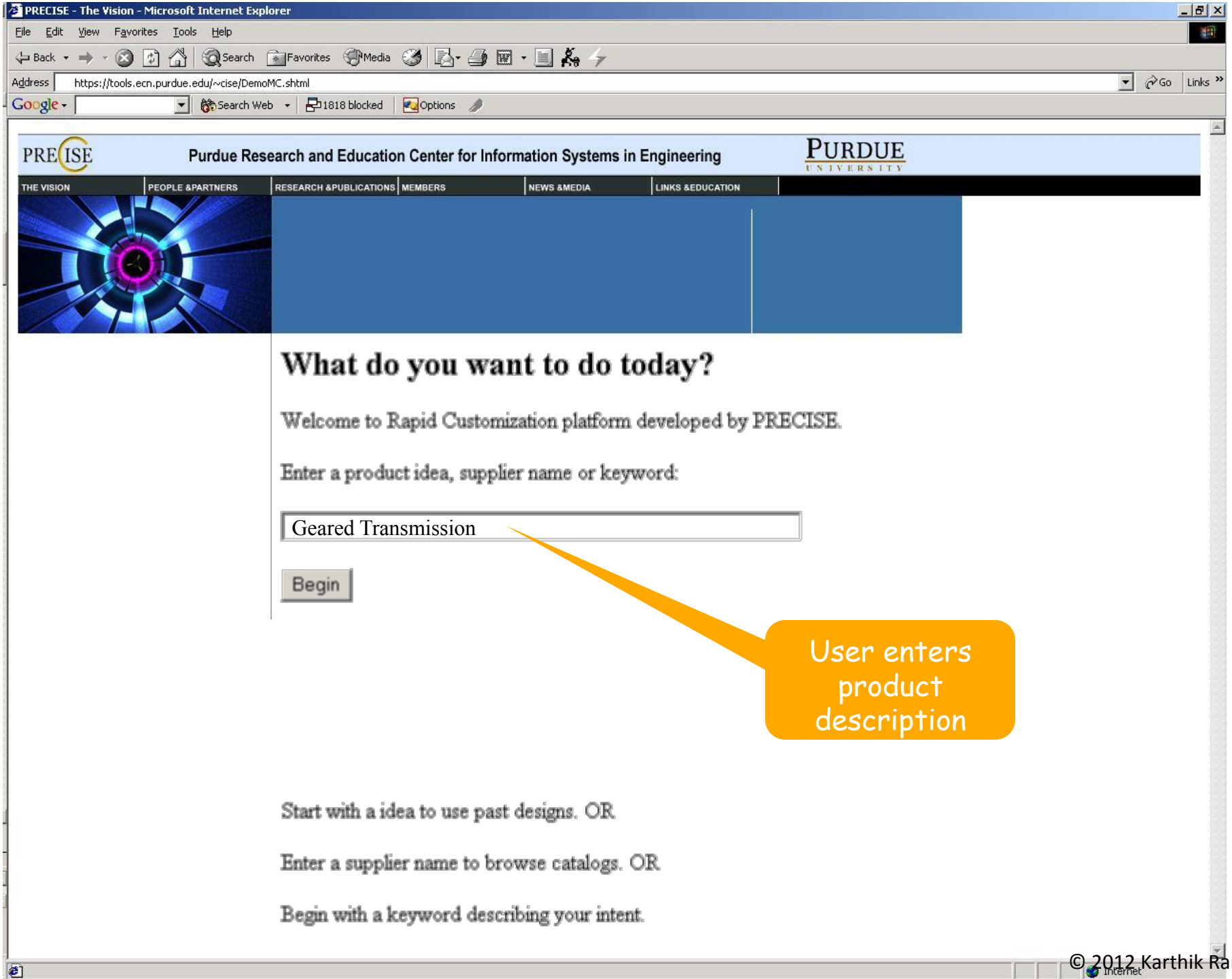

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Please wait while we search for concepts . . . Done

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Concept Search Results

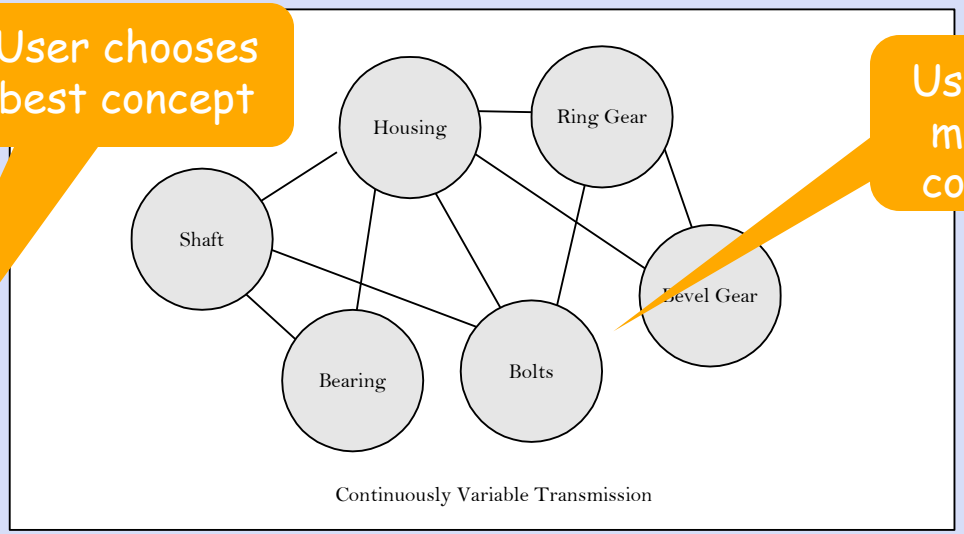
Planetary Gear train

Automotive transmission

Continuously Variable Transmission

User chooses best concept

Concepts | Constraints | Model | Suppliers



Continuously Variable Transmission

User can modify concept

< Back Next >

Please choose a concept to proceed. After choosing press "Configure".

Searching for "Geared Transmission"...

n Complete.

ncepts ...

Displaying...Done

Concept Chosen.

Reading Concept...

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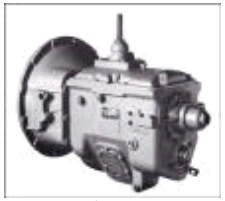
Design Parameters & Constraints

Concept Search Results

Planetary Gear train



Automotive transmission

Continuously Variable Transmission

Concepts | **Constraints** | Model | Suppliers

Continuously Variable Transmission

Global Constraints

Loads :	Medium			☐ Ignore
Gear Ratio :	min : 0.25	max : 4		☐ Ignore
Max Size :		cm	Diameter	☑ Ignore
	12	inch	Length	☐ Ignore

< Back Configure >

Please provide the performance parameters of the product.

Searching for "Geared Transmission"...

Search Complete.

10 Concepts found...

Displaying...Done

Concept Chosen.

Reading Concept...

Retrieving Global Constraints...

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Viable Configured Product

Customized Catalog

Custom Catalog

Bearings

- Ball Bearing from CIE Bearing
- Bearing from Timken

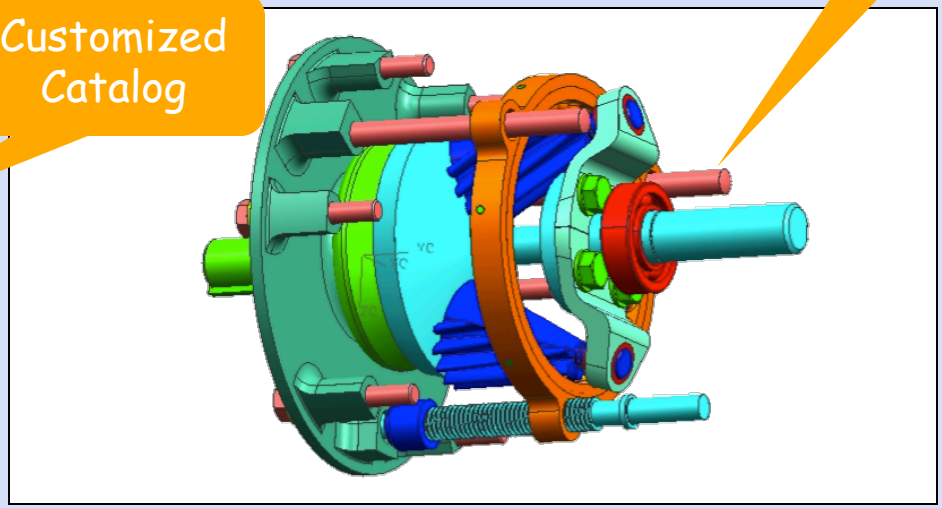
Gears

- Gear from Cincinnati
- Gear from Fairfield
- Gear from Boston Gear
- Gear from Boston Gear

Shafts

- Shaft from

Concepts | Constraints | **Model** | Suppliers



< Back Finalize

Drag and drop appropriate componts from the catalog to create the product.

```
Searching for
"Geared
Transmission"...

Search Complete.

10 Concepts
found...

Displaying...Done

Concept Chosen.

Reading
Concept...

Retrieving Global
Constraints...

Searching for
suppliers... 28
found.

Extracting
components from
suppliers... Done

Generating Model.
```

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Address https://tools.ecn.purdue.edu/~cise/DemoMC.shtml

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BoM is generated across diverse suppliers

Custom Catalog

Bearings

- Ball Bearing from CIE Bearing
- Bearing from Timken

Gears

- Gear from Cincinnati
- Gear from Fairfield
- Gear from Boston Gear
- Gear from Boston Gear

Shafts

- Shaft from

Concepts | Constraints | Model | **Suppliers**

Tihoe Industrial Co

FAIRFIELD GEARED FOR EXCELLENCE

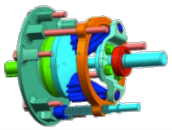
TIMKEN

CIE BEARING

Boston Gear

Tirosh David Quality Castings Ltd.

(5) Bolt P/N 967830	(5) Bolt P/N 933042
(2) Bevel Gear P/N 59002B	(2) Conical Gear P/N 57330V
(2) Ball Bearing P/N 15902	(1) Keyed Shaft P/N 23901
(2) Journal Bearing P/N 15900	
(1) Outer Casing P/N 14902	(1) Face Plate P/N 13202



< Back RFQ>

Please review the final Bill of Materials and request quote from suppliers.

```
10 Concepts found...

Displaying...Done

Concept Chosen.

Reading Concept...

Retrieving Global Constraints...

Searching for suppliers... 28 found.

Extracting components from suppliers... Done

Generating Model.

Creating Bill of Material... Done
```

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Thank You!

Your Request has been forwarded to the suppliers. Your order will be confirmed soon.

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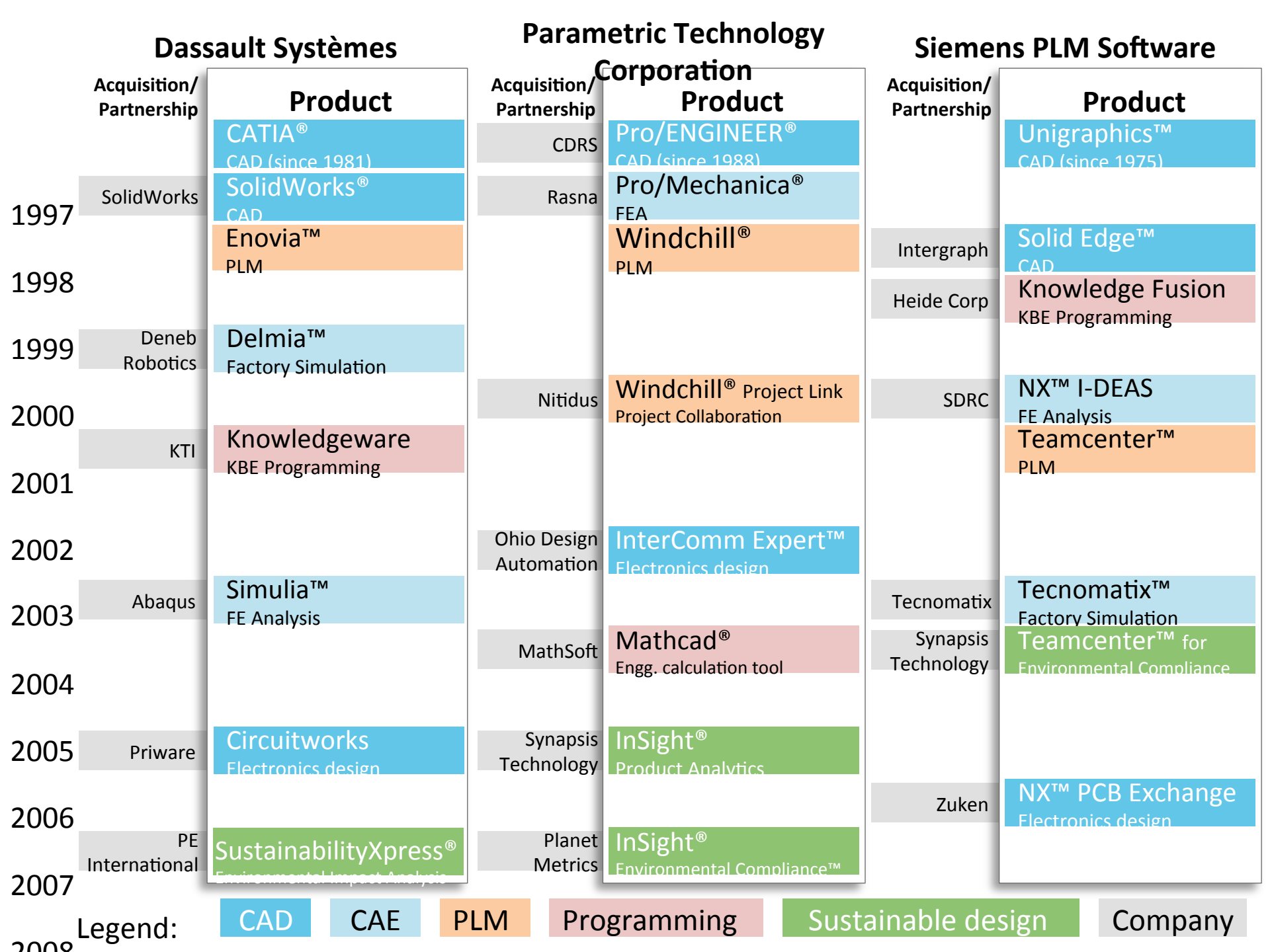
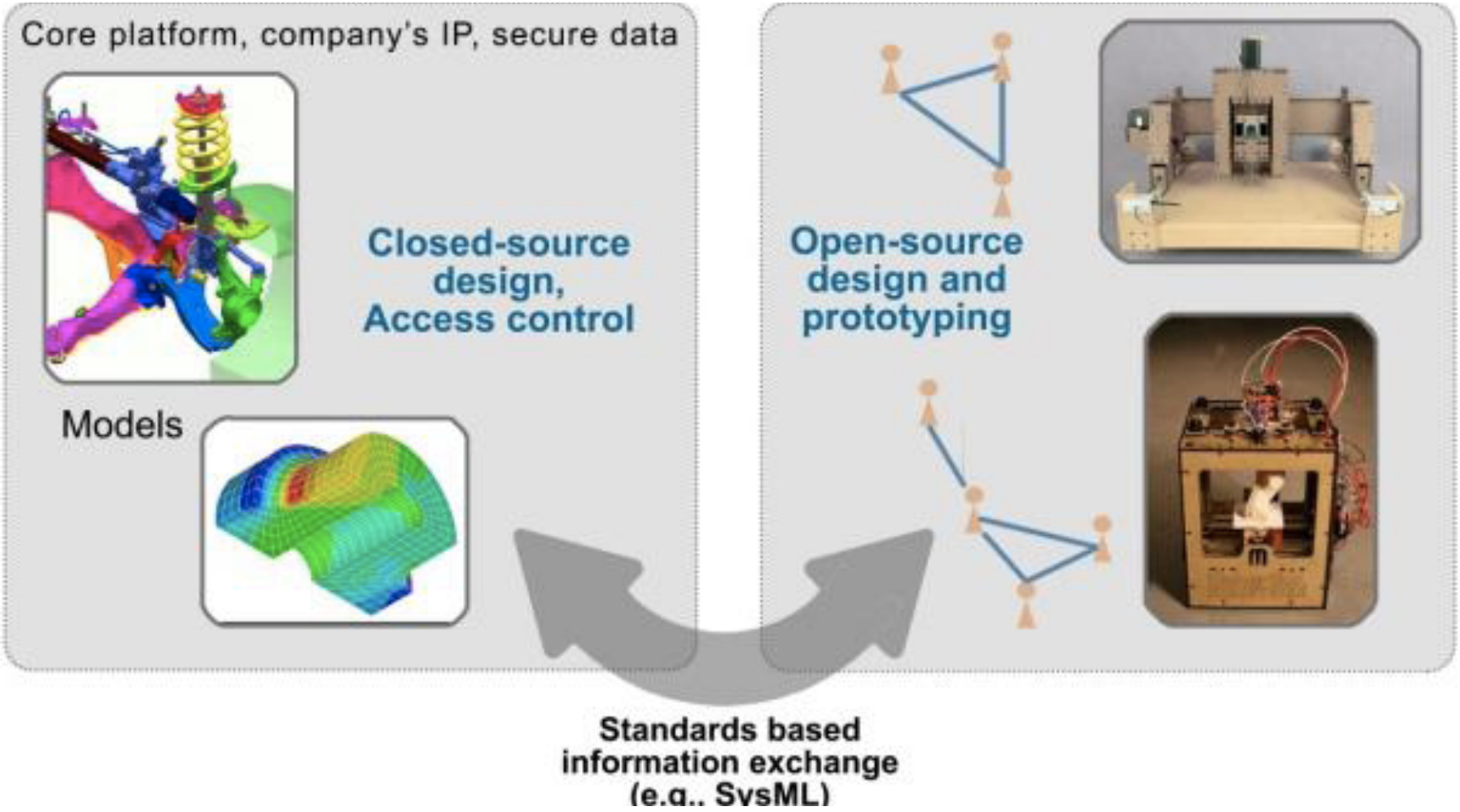

Dassault Systèmes
Parametric Technology Corporation
Siemens PLM Software
Acquisition/ Partnership
Product
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
SolidWorks
CATIA®
CAD (since 1981)
SolidWorks®
CAD
Enovia™
PLM
Deneb Robotics
Delmia™
Factory Simulation
KTI
Knowledgeware
KBE Programming
Abaqus
Simulia™
FE Analysis
Priware
Circuitworks
Electronics design
PE International
SustainabilityXpress®
CDRS
Pro/ENGINEER®
CAD (since 1988)
Rasna
Pro/Mechanica®
FEA
Windchill®
PLM
Nitidus
Windchill® Project Link
Project Collaboration
Ohio Design Automation
InterComm Expert™
Electronics design
MathSoft
Mathcad®
Engg. calculation tool
Synapsis Technology
InSight®
Product Analytics
Planet Metrics
InSight®
Environmental Compliance™
Intergraph
Unigraphics™
CAD (since 1975)
Solid Edge™
CAD
Heide Corp
Knowledge Fusion
KBE Programming
SDRC
NX™ I-DEAS
FE Analysis
Teamcenter™
PLM
Tecnomatix
Tecnomatix™
Factory Simulation
Synapsis Technology
Teamcenter™ for Environmental Compliance
Zuken
NX™ PCB Exchange
Electronics design
Legend:
CAD
CAE
PLM
Programming
Sustainable design
Company

Open-and-closed systems



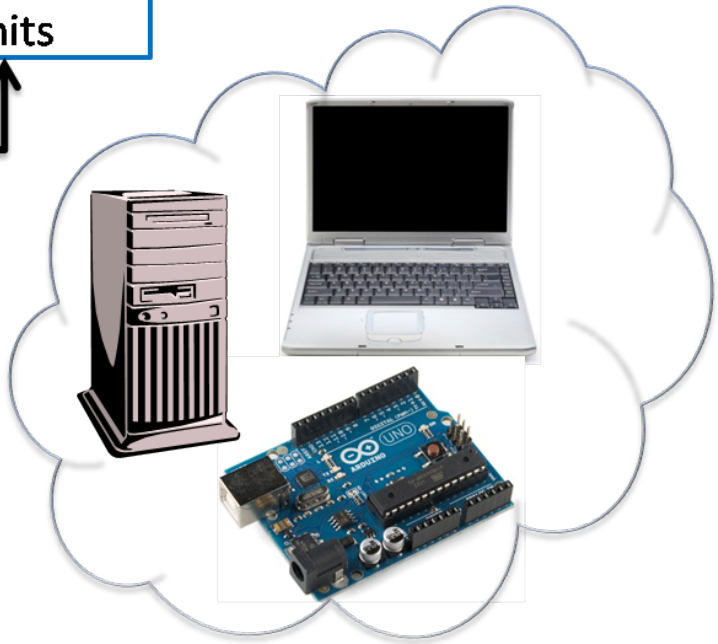
Platforms with a core and “APPS” with multi-company models for product innovation

User & Environment

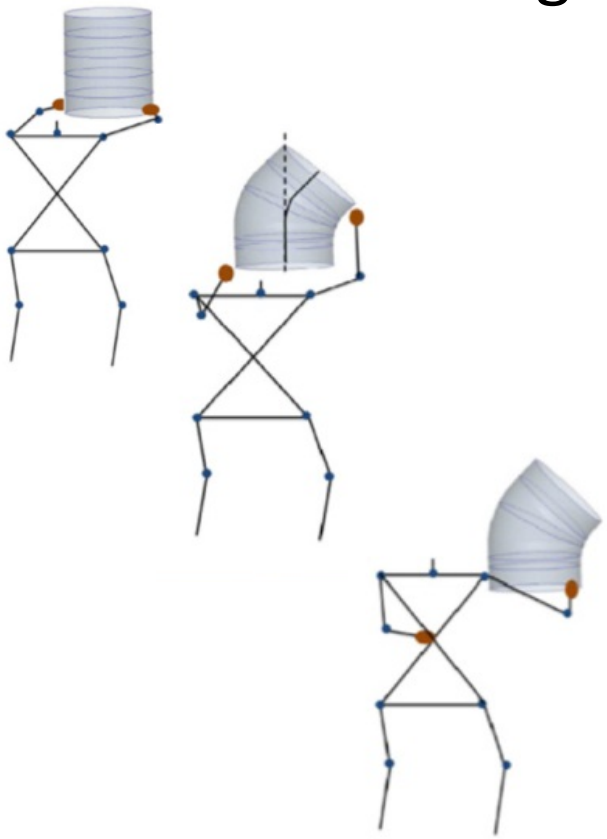
Visualization/ Feedback Units

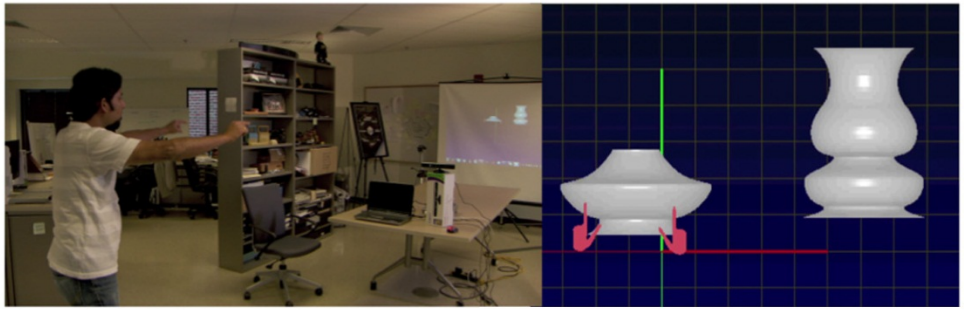
Data Processing Units

Human & Environment Data Capturing Units



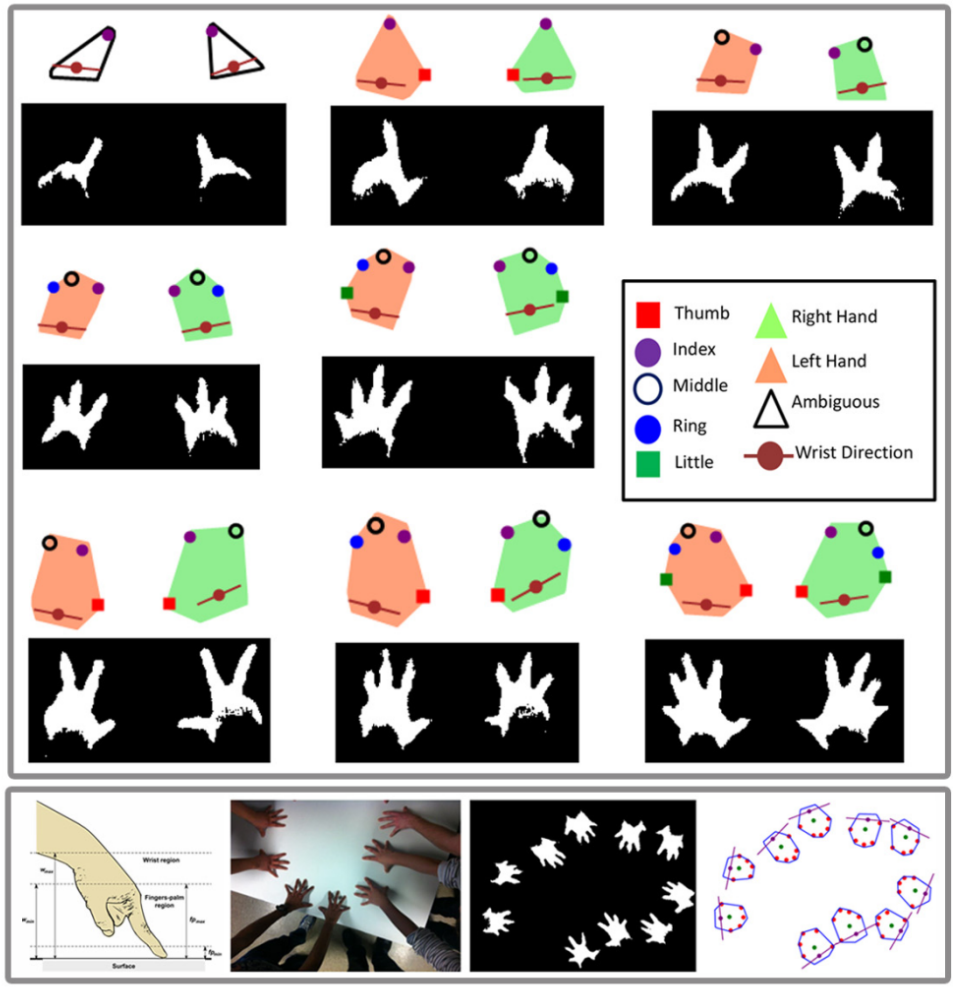
Handy-Potter: Rapid 3D Shape Exploration Through Natural Hand Motions





Vinayak, Sundar Murugappan, Cecil Piya, Karthik Ramani

Handy-Potter: Rapid 3D Shape Exploration Through Natural Hand Motions
Proceedings of the ASME 2012 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference IDETC/CIE 2012, August 12-15, 2012,



Murugappan, S., Vinayak, Elmqvist, N., Ramani, K., Recovering Touch Posture and Identity Using Depth Cameras on a Pen+Touch Tabletop Interface, Proceedings of the ACM Conference on User Interface Software and Technology, 2012

Challenges and Opportunities

- A Flexible Architecture for Open Source Communities in D&M creation CPS [old top down vs. innovation based on evolution based on self organization]
- Model systems with embedded problems that represent scaled or complex systems
- Core research to create ideas for tools and methods that will allow for creative exploration of a multitude of "X" CPS products
- Computational architectures and business models.
- Social, economic and business evolution: problem has to be explored

Acknowledgements

- Vinayak, Sundar Murugappan, Cecil Piya, Senthil Chandrasegaran, Ayan Sinha
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